INVESTIGATION OF EFFECTIVE ATOMIC NUMBER FOR SOME COMPOSITE MATERIALS

Synopsis for Ph.D. degree

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INTRODUCTION

Most of the materials used in daily life are composed of two or more elements and can be classified in the categories of compounds or mixtures. Such materials can be grouped together under the common name of composite materials and covers a large number of materials such as alloys, polymers, biological materials etc. Composite materials have played an important role in the development of modern technology. The knowledge of physical parameters such as mass attenuation coefficients, atomic and electronic cross-sections, effective atomic number and electron density plays an important role in understanding the physical properties of such materials.

To understand the photon interactions with composite materials, these materials have been categorized by a unique number, which is known as "effective atomic number" (similar to the atomic numbers for elements). The parameter ''effective atomic number'' signifies that at a given energy, photons would interact with a composite material in a similar way as a single element of atomic number equivalent to that composite material.

The effective atomic number (Z_{eff}) has to be calculated from atomic numbers of the constituent elements, weighted according to the different partial photon interaction processes. Therefore, effective atomic number is an energy dependent parameter.

Many characteristics of composite material can be visualized with this number. The effective atomic number is important in fundamental physics and many applied fields and the accurate values of effective atomic number for several materials at different photon energies corresponding to X- and γ-rays are essential for some fields such as nuclear and radiation physics, radiation dosimetry, biological, medical, agricultural and industry.

REVIEW OF LITERATURE

Following Hine's [1] suggestions, many researchers had contributed in finding out the effective atomic numbers of composite materials, some of which has been discussed year wise as follows:

El-Kateb et al. [2] measured total interaction cross-sections and effective atomic numbers of some alloys in the energy range of 81 - 1332 keV. Duvauchelle et al. [3] established a theoretical relation which simulates the result of a Rayleigh to Compton scattering ratio to calculate effective atomic number of aqueous solutions with different concentrations of eight elements, having Z values ranging from 3 to 64. Murty et al [4] evaluated the effective atomic numbers for W/Cu alloy of two compositions, 65:35 and 60:40 for the photon energy range 60-400 keV. Nayak et al [5] determined effective atomic numbers (Zeff) of three polymers, an alloy, a compound and an element for photoelectric process at 59.54 keV. Singh et al. [6] calculated the effective atomic number for xZnO, 2xPbO (1-3x), B_2O_3 (x= 0.1–0.26) glasses by measuring the mass attenuation coefficients at photon energies 511, 662, 1173 and 1332 keV. Icelli et al. [7-8] calculated effective atomic numbers of some vanadium and nickel compounds, CuCoNi alloys against changing Ni contents respectively. Gowda et al. [9] calculated the effective atomic numbers of the amino acids at the energies 30.8, 35.0, 81.0, 145, 276.4, 302.9, 356, 383.9, 661.6, 1173 and 1332.5 keV. Singh et al. [10] determined the effective atomic number of composite materials by using the method of Rayleigh to Compton scattering ratio at the scattering angle of 145^o. Manohara et al. [11-12] calculated the effective atomic numbers amino acids in the wide energy range of 1 keV–20 MeV and 1 keV–100 GeV respectively. Singh et al. [13-14] computed the mass attenuation coefficients, effective atomic numbers and electron densities in the energy range of 10 keV - 100 GeV for some commonly used solvents and some organic acids in the energy range of 1 keV to 100 GeV respectively. Donativi et al. [15] provided the Rayleigh to Compton ratio (R/C) for elements and compounds with low atomic number ($5 \leq Z \leq 12$). Kaewkhao et al. [16] calculated effective atomic numbers of the Cu-Zn alloys at 356, 511, 662, 835 and 1275 keV gamma-ray energies. Cevik et al. [17] measured the effective atomic numbers CdSe, CdTe semiconductor at different energies from 9.7 to

87.3 keV. Manohara et al. [18] reported a comprehensive and consistent set of formulas for calculating the effective atomic number and electron density for all types of materials and for all photon energies greater than 1 keV. Icelli et al. [19-21] measured effective atomic numbers for some boron compounds, the trommel sieve waste (TSW), polypyrrole, holmium doped and undoped layered semiconductor in the X-ray energy range from 15.746–40:930 keV using Si(Li) detector. Singh et al. [22] measured the saturation depth due to multiple scattering of 320 keV photons from targets of different atomic numbers ($13 \leq Z \leq 79$) by varying thickness of the target (elements and alloys) and suggested another technique for evaluating the effective atomic number. Recently Manohara et al. [23] measured effective atomic number for $CaO–SrO–B_2O_3$, $PbO–B_2O_3$, $Bi_2O_3–B_2O_3$ and $PbO–Bi_2O_3–B_2O_3$ glasses in the energy range of 1 keV to 1 GeV.

From survey of literature, it has been observed that following methods have been employed for determining the effective atomic number:

1. Transmission method:
    i. Ratio of atomic to electronic cross-section
    ii. Interpolation of molecular cross-section values
2. Intensity ratio of Compton to Rayleigh peak.
3. Based on saturation depth due to multiple scattering of photons.

However, all these methods were rarely applied to a single composite material. So, there is a dire need to conduct the comparative experimental investigations to obtain effective atomic number by different methods, especially in the lower and higher incident photon energies where discrepancies were observed in theoretical computations.

OBJECTIVES

Since effective atomic number is very important parameter for radiation physicists and nuclear engineers for dose computations and reactor shield designing, this value must be standardized and precise. Although many researchers had contributed in computing effective atomic number and related parameters theoretically, still it lacks experimental verification. So there is dire need of systematic experimental investigations for the determination of effective atomic number of composite materials.

Keeping this in view, it is worthwhile to pursue experimental investigations of effective atomic number for some composite materials such as polymers, alloys and glasses at some incident photon energies. The main objectives of the work are:

1. To find the dependence of effective atomic number on different parameters such as
    - (i) Incident photon energy.
    - (ii) Physical state of the material.
    - (iii) Thickness of the material.
2. To provide an empirical relation for determining effective atomic number at different energies.
3. To compare effective atomic number computed by different theoretical formulations with experimentally measured values.
4. To check the feasibility of using the selected composite material as gamma ray shielding material.
5. Some other photon interaction parameters such as mass attenuation coefficient, electron density, buildup factor etc of the selected composite materials.

REFERENCES

1. G. J. Hine, Phys. Rev. **85** (1952) 725.
2. A.H. El-Kateb and A.S. Abdul Hamid, Appl. Radiat. Isot**. 42** (1991) 303.
3. P. Duvauchelle, G. Peix and D. Babot, Nucl. Instrum. & Meth. **B155** (1999) 221
4. V.R.K. Murty, D.P. Winkoun and K.R.S. Devan, Appl. Radiat. Isot. **53** (2000) 945.
5. N. Govinda Nayak, M.G. Vijaya and K. Siddappa, Radiat Phys. Chem., **61** (2001) 559.
6. H. Singh, K. Singh, L. Gerward, K. Singh, H.S. Sahota, and R. Nathuram, Nucl. Instrum. & Meth. **B207** (2003) 257.
7. O. Icelli and S. Erzeneoglu, J. Quant. Spectrosc. Radiat. Transfer, **85** (2004) 115.
8. O. İçelli, S. Erzeneoğlu, İ.H. Karahan and G. Çankaya, J. Quant. Spectrosc. Radiat. Transfer, **91** (2005) 485.
9. S. Gowda, S. Krishnaveni and R. Gowda, Nucl. Instrum. & Meth. **B239** (2005) 361.
10. M.P. Singh, B.S. Sandhu and Bhajan Singh, Nucl. Instrum. & Meth. **A580** (2007) 50.
11. S.R. Manohara and S.M. Hanagodimath, Nucl. Instrum. & Meth. **B264** (2007) 9.
12. S.R. Manohara and S.M. Hanagodimath , Nucl. Instrum. & Meth. **B258** (2007) 321.
13. T. Singh, P. Kaur and P.S Singh, J. Radiol. Prot**. 27** (2007) 79.
14. T. Singh, P. Kaur, and P.S. Singh, Nucl. Sci. Engg **156** (2007) 229.
15. M. Donativi, S. Quarta , R. Cesareo and A. Castellano, Nucl. Instrum. & Meth. **B 264** (2007) 189.
16. J. Kaewkhao, J. Laopaiboonb and W. Chewpraditkul, J. Quant. Spectrosc. Radiat. Transfer **109** (2008) 1260.
17. U. Cevik, E. Bacaksiz, N. Damla and A. Celik, Radiat. Measure. **43** (2008) 1437.
18. S.R. Manohara, S.M. Hanagodimath, K.S. Thind and L. Gerward, Nucl. Instrum. & Meth. **B266** (2008) 3906.

19. O. İçelli, S. Erzeneoğlu and R. Boncukçuoğlu, Nucl. Instrum. & Meth. **B266** (2008) 3226.
20. O. İçelli, Salih Erzeneoğlu and Mustafa Sağlam, Ann. Nucl. Energy **35** (2008) 432.
21. O. Ïçelli, Nucl. Instrum. & Meth. **A600** (2009) 635.
22. M. Singh, B. Singh and B.S. Sandhu, Phys. Scr. **79** (2009) 035101(pp8).
23. S.R. Manohara and S.M. Hanagodimath, J. Nucl. Mater. **393** (2009) 465.